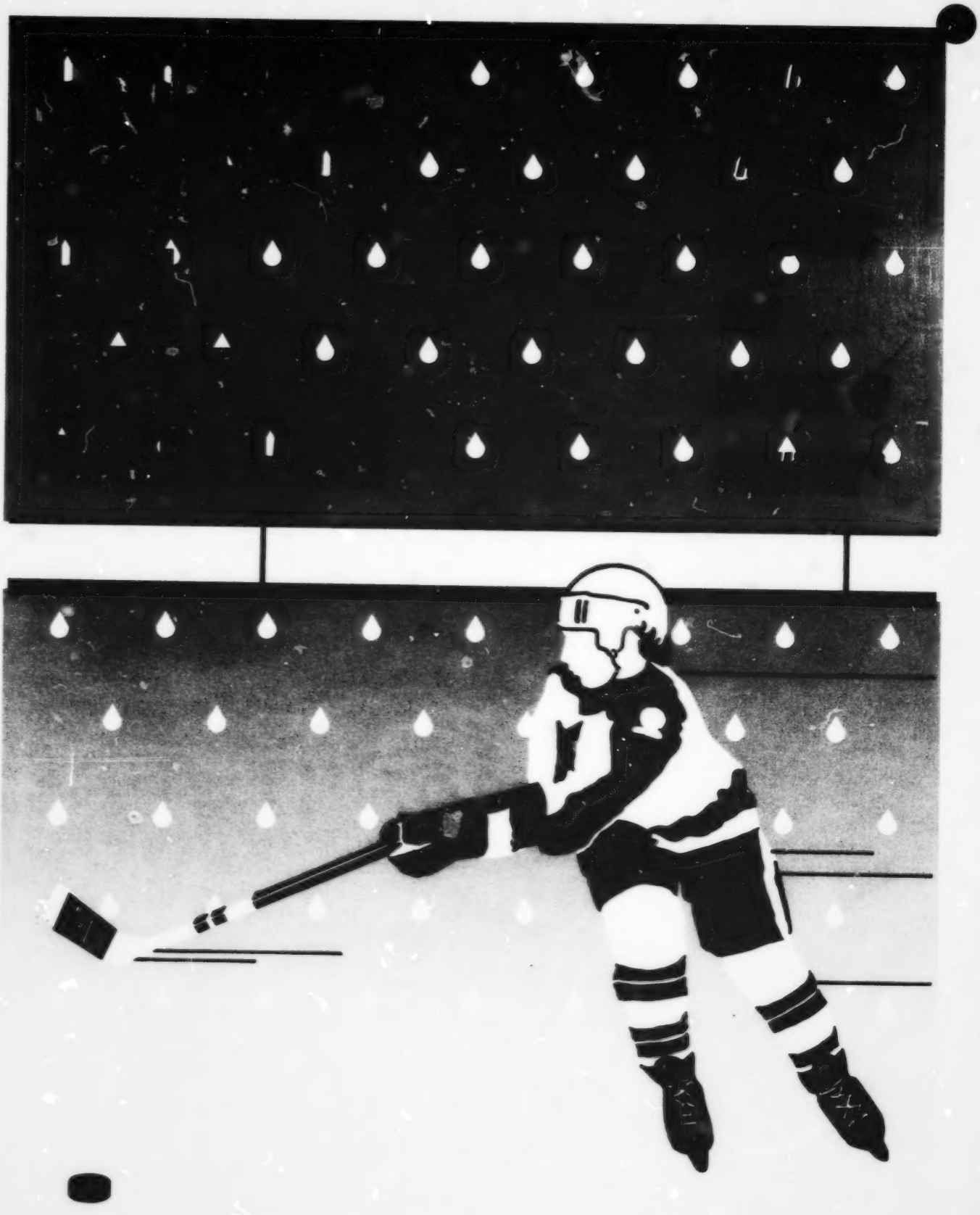

Ontario Ministry of Tourism and Recreation

Alberta RECREATION AND PARKS

INTERPROVINCIAL SPORT AND RECREATION COUNCIL

National Research Council Canada

87-05010/

INDOOR ICE ARENAS

HUMIDITY CAUSED PROBLEMS AND SUGGESTED SOLUTIONS

ISRC Facility Subcommittee

National Research Council

Institute for Research in Construction

Foreword and Acknowledgement

Reports have been received from across Canada on premature deterioration of indoor pool and arena buildings. The following technical paper was prepared to assist arena managers to start to solve their common problems. It identifies the likely causes of various humidity-related problems and suggests possible solutions. This report is not, however, a substitute for professional advice. Architects, engineers or other building professionals should be consulted.

This technical paper on arenas and its companion volume on pools, "Indoor swimming pools - humidity-caused problems and suggested solutions," are the results of a partnership between the:

Interprovincial Sport and Recreation Council,
Facilities Subcommittee,
National Research Council of Canada, Institute for Research in Construction,
Ontario Ministry of Tourism and Recreation,
Alberta Recreation and Parks and
Presidents of provincial facility associations from across Canada.

Principal research and writing for these manuals was completed by Charles S. Strelka, P.Eng., MRAIC, National Research Council, Institute for Research in Construction. Anne Zavaros, University of Waterloo, provided editorial comments and the Ontario Ministry of Tourism and Recreation acted as a project manager. Alberta Recreation and Parks kindly arranged for printing and distribution.

A special thanks is due to the many recreation facility professionals and others who reported on humidity problems they had encountered as well as reviewing earlier drafts of the manual.

Please provide your comments, experiences or suggestions for humidity control to:

ISRC Pool and Arena Humidity Control Project
c/o Recreation Resources Section
Ontario Ministry of Tourism and Recreation
77 Bloor Street West, 8th Floor
Toronto, Ontario
M7A 2R9

or

Charles Strelka, P.Eng. MRAIC
V. W. Kuchar and Associates Architects Ltd.
37 Birch Avenue,
Ottawa, Ontario. K1K 3G5

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I) INTRODUCTION

At the present time, we are experiencing unique operational problems with the aging inventory of ice arenas. Most of these buildings were constructed during the "golden age" of recreational building funding - in the 60's and 70's. Now, after 15-25 years of operation, the problems caused by daily use, and in some cases the inadequacies of design and/or construction, are becoming more pronounced and unacceptable.

Problems encountered range from building maintenance, high energy use, high humidity levels, to structural failure. Many of these problems are, of course, closely related; this is not always recognized. The problem visible to the owner/operator - for instance water dripping on the ice - may cause the operator to complain about the high cost of ice preparation and the poor quality of the last year's roofing job, without realizing that the real cause of the problems is the high level of humidity in the arena. The humidity leads to condensation on the underside of the roof structure. Thus the water dripping down ruins the ice surface. This condensate is the most frequent cause of problems encountered.

In the course of a preliminary study conducted in the fall of 1985, we were able to examine several recreational buildings in various stages of disrepair. For the sake of owners/operators, who face a similar situation, the most frequent problems are described, causes are

stated and possible solutions are suggested. Where remedial action to the problem was taken, information on results will be included.

II) TYPICAL INDOOR ICE ARENA

In the course of investigation, the typical indoor ice skating arena was a prefabricated steel building. Some service space additions were either of steel construction or were built of brick or concrete block. The arena space itself had a minimal slope metal or wood planking roof over a steel frame bearing structure. The roof structure was open to the space below (i.e. a ceiling was not installed over the ice rink). Thermal insulation, when provided, was of varying thickness, suspended below the underside of the roof and covered by a heavy vinyl liner sheet. This vinyl sheet provided the vapour barrier function. Exterior walls beginning at the finished grade level were usually of uninsulated concrete blocks and changed to steel frame and metal infill panels with minimal insulation (approximately at 0.9 - 1.5 m above the top row of seats). The various service rooms and spaces, located below the seating area or as additions to the arena building, had uninsulated exterior walls (Figure 1).

III) TYPICAL PROBLEMS REPORTED BY THE OWNERS/OPERATORS

Problem 1 The roof leaks, water is dripping on the ice; destroying it, or freezing again, making for irregular surface of the ice sheet.

TYPICAL ARENA

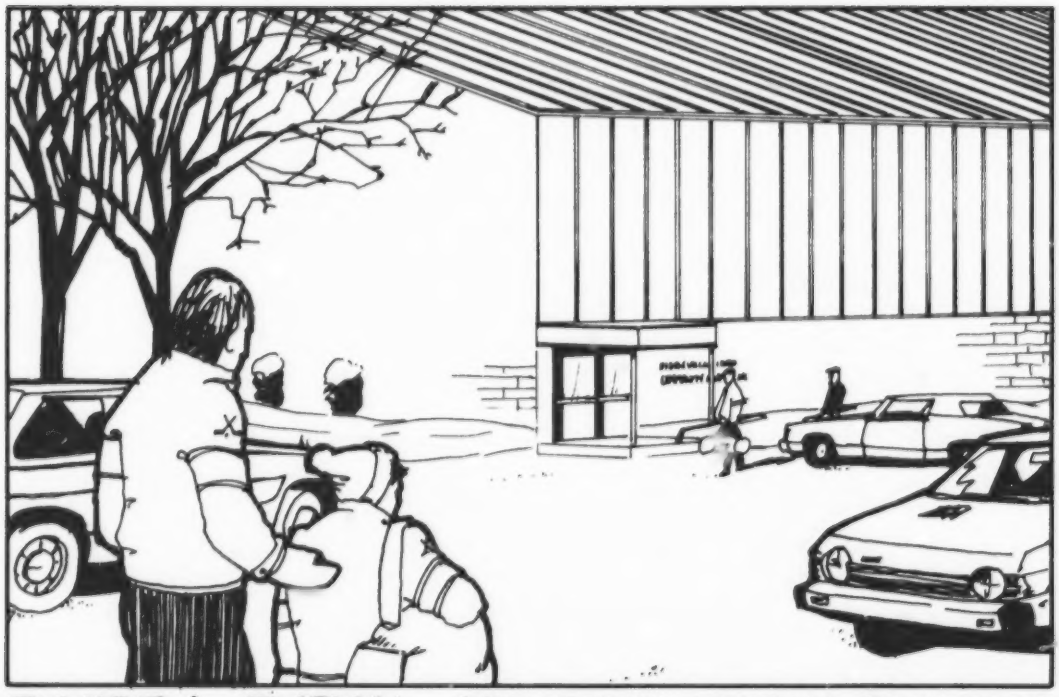

FIGURE 1. TYPICAL ICE RINK ARENA BUILDING

Problem 2 Condensation is building up on the underside of the insulation liner and on the roof bearing structure, with similar effects as in Problem 1.

Problem 3 Condensate is trapped inside the insulation causing the liner sheet to sag by its weight. Water then leaks through damaged seams of the liner onto the ice and spectators.

Problem 4 There are reported cases of condensate trapped and frozen inside the insulation and later falling in chunks. Several arenas had to install wire netting below the insulation layer to prevent injury to players or spectators.

Problem 5 The metal parts of exterior walls are sweating heavily and the condensed water is dripping on the lower block walls, wetting the concrete and causing efflorescence on the inside and/or outside face of the wall.

Problem 6 The vinyl liner of the insulation and inner metal wall lining sheets are easily damaged.

Problem 7 The metal elements of the building are rusting.

Problem 8 The energy bills are too high.

Problem 9 The ice making period is too long and costly.

IV) DISCUSSION OF THE PROBLEMS

a) Problem 1 - The Leaking Roof

The leaking roof in steel structures (aside from faulty installation which probably would have shown immediately after the erection of the building) is usually caused by one of the following:

The metal sheets are attached to the purlins by self tapping screws sealed by silicon sealant or rubber washers. As a result of temperature differences, between sunny days and cool nights, the roof structure "works" and the repeated expansion and contraction of the metal structure loosens the screws. Periodical tightening of the screws is required. However, by tightening the screws, the silicon seal will eventually break, and the roof could start to leak.

Another place where the roof leaks is along the edges. In many cases, the detailing of the roof edge, suitable for unheated metal storage buildings, was used for an arena building with a completely different indoor environment. The main seating areas are necessarily arranged along the longer exterior wall. The warm air rising from the temporarily heated seating areas, warms the roof at the lower part of its slope, melting the snow there. When the melted water reaches the cold edge of the roof, it freezes and eventually forms an ice dam. Water ponding behind the ice dam can easily penetrate the roof surface at the metal sheets overlapping

joints and either be trapped in the insulation blanket or drip directly onto the ice and/or seating area. Using heating cables in this location of the roof may eventually alleviate part of the problem. However, the narrow roof overhang, generally used in this type of construction, does not provide for good run-off; thus, the melted water may be pushed by wind action back into the roof structure (especially when the closure strip inserts are missing, as often is the case). When the weather is colder, heavy icicles may form, adhering to the building. These icicles later melt on the building surface, increasing the moisture around the structure (see Figure 2).

Recommendations

It is essential to correct this problem wherever it occurs. The edge of the roofing sheet must be extended over the eave box section and project at least 100-150 mm to allow for a proper roof run-off. This reconstruction may include cutting and removing part of the existing roofing sheet and providing a new sheet section all around the roof edge. See accompanying details in Figure 3. Broken seals at fasteners (silicone or rubber) must be checked and/or replaced when the screws are tightened.

b) Problem 2, 3 & 4 - Roof and Insulation

The common cause of these problems is humid air. The activities taking place in an indoor ice arena are, by their own nature,

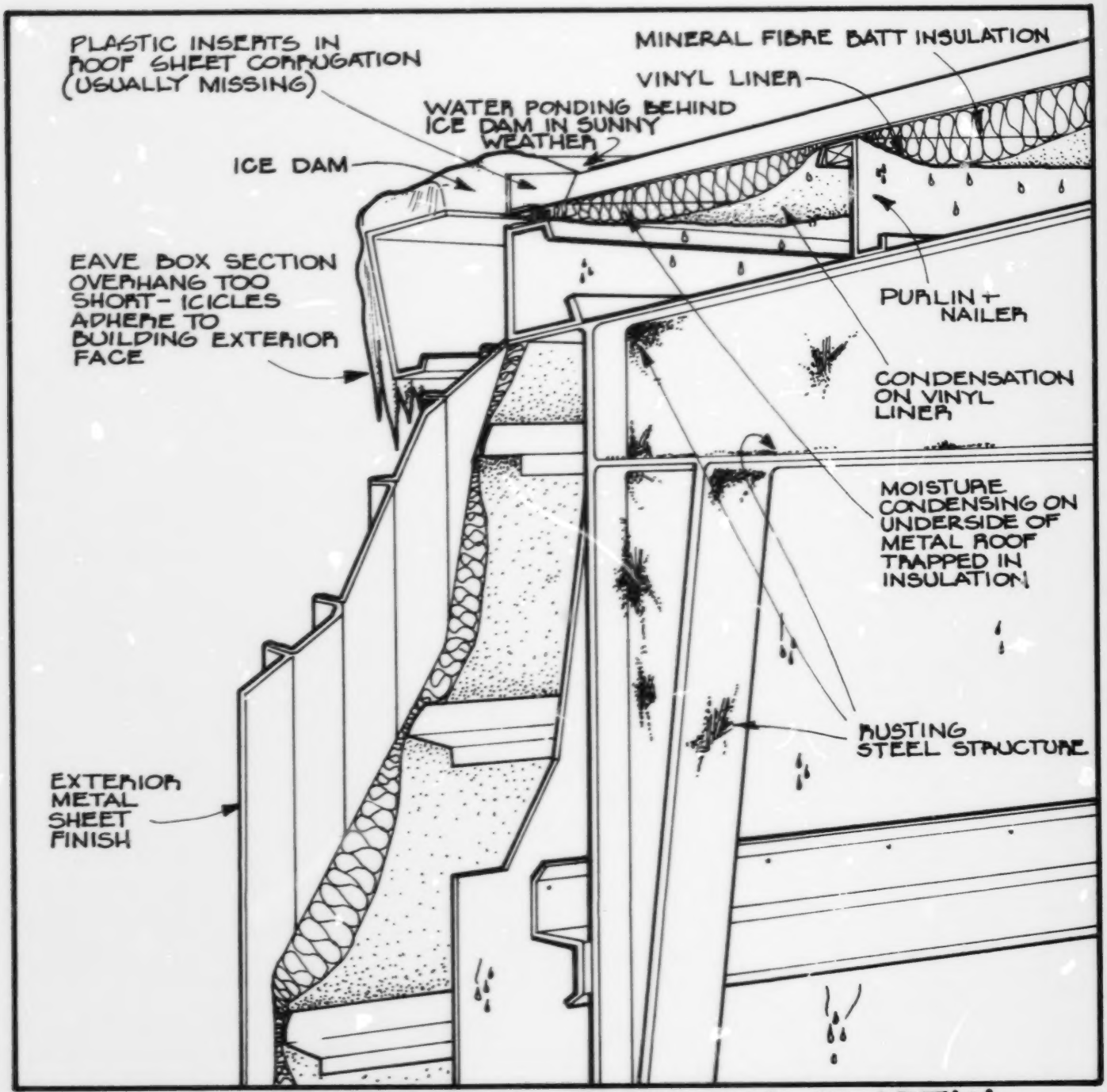
PLASTIC INSERTS IN ROOF SHEET CORRUGATION (USUALLY MISSING)
MINERAL FIBRE BATT INSULATION
VINYL LINER
WATER PONDING BEHIND ICE DAM IN SUNNY WEATHER
ICE DAM
EAVE BOX SECTION OVERHANG TOO SHORT - ICICLES ADHERE TO BUILDING EXTERIOR FACE
PURLIN + NAILER
CONDENSATION ON VINYL LINER
MOISTURE CONDENSING ON UNDERSIDE OF METAL ROOF TRAPPED IN INSULATION
RUSTING STEEL STRUCTURE
EXTERIOR METAL SHEET FINISH

FIGURE 2. CONDENSATION PROBLEMS AT ARENA ROOF AND UPPER PART OF METAL EXTERIOR WALL

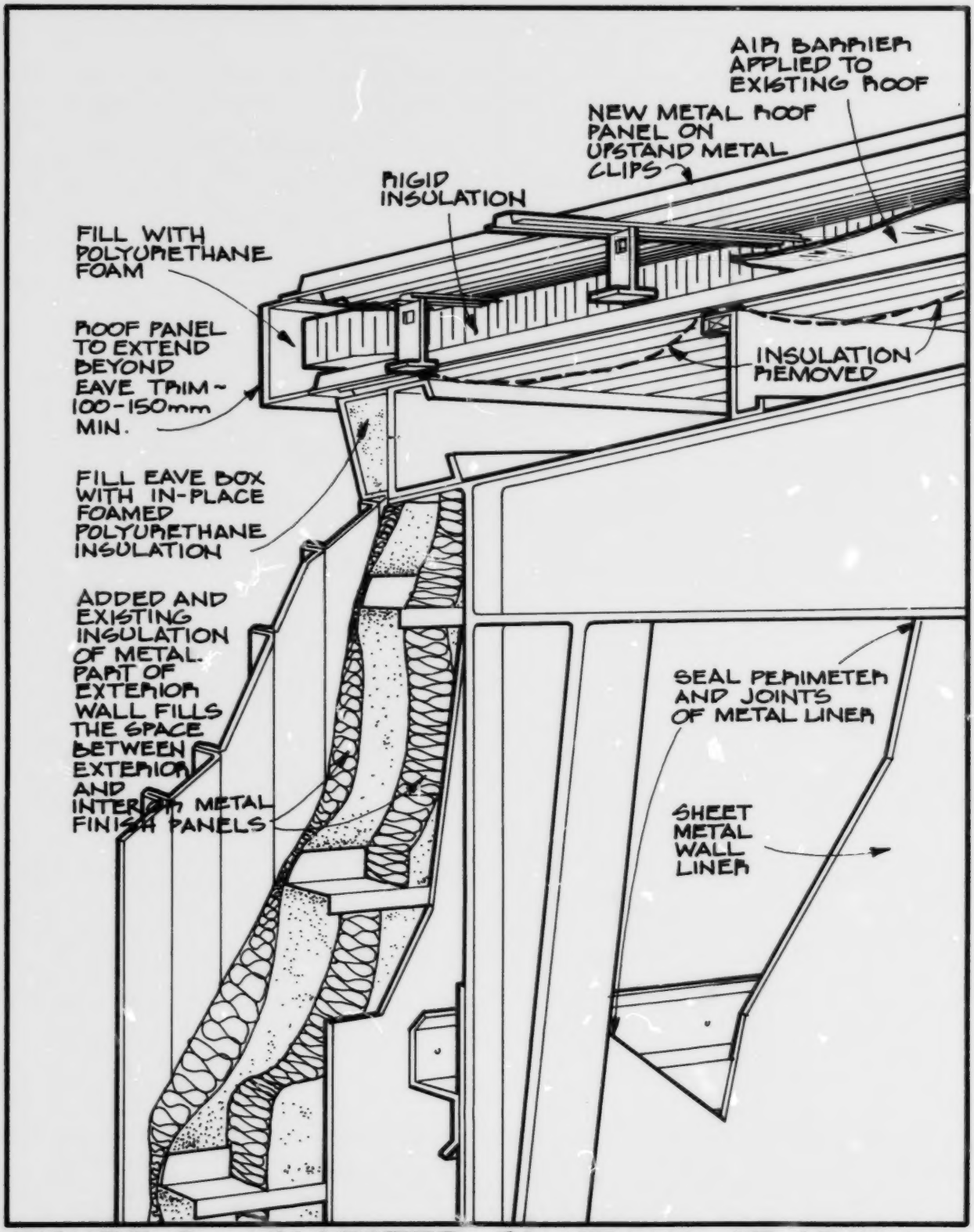
AIR BARRIER APPLIED TO EXISTING ROOF
NEW METAL ROOF PANEL ON UPSTAND METAL CLIPS
RIGID INSULATION
FILL WITH POLYURETHANE FOAM
ROOF PANEL TO EXTEND BEYOND EAVE TRIM ~ 100-150mm MIN.
INSULATION REMOVED
FILL EAVE BOX WITH IN-PLACE FOAMED POLYURETHANE INSULATION
ADDED AND EXISTING INSULATION OF METAL PART OF EXTERIOR WALL FILLS THE SPACE BETWEEN EXTERIOR AND INTERIOR METAL FINISH PANELS
SEAL PERIMETER AND JOINTS OF METAL LINER
SHEET METAL WALL LINER

FIGURE 3. SUGGESTED SOLUTIONS AT ARENA ROOF AND UPPER PART OF METAL EXTERIOR WALL

conducive to increasing the relative humidity of the air. Flooding the rink while preparing ice (up to 14 times a day), evaporation from the ice itself, and moisture added to the air just by breathing of skaters and spectators, are sources of humidity that cannot be eliminated. When the seating areas are heated by natural gas, the by-products of gas combustion increase the relative humidity of the air even more (see footnote* and Figure 4).

What does the term "relative humidity of the air" (in technical literature sometimes indicated as RH) mean and how does it affect the building? The amount of moisture air is able to contain depends on its temperature. Higher temperature permits greater capacities of moisture in air. When warm, humid air comes in contact with a cool surface, it cools down until it reaches what is described as the "dew point temperature". At this point, the moisture contained in the air condenses into water (or ice if the temperature of the surface is below 0°C, see Figure 5).

In an arena, the rising warm air first comes into contact with the cold surfaces of the roof supporting structure (joists and/or beams). Then, the air contacts the insulation liner and, in the

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* -evaporation from 1 m^2 flooded ice surface — 0.1 L/h water
-breathing 1 person stationary — 0.1 L/h water
-1 person exercising — 0.3 L/h water
-natural gas heating
burning of 1 m^3 of gas produces — 2 m^3 water vapour

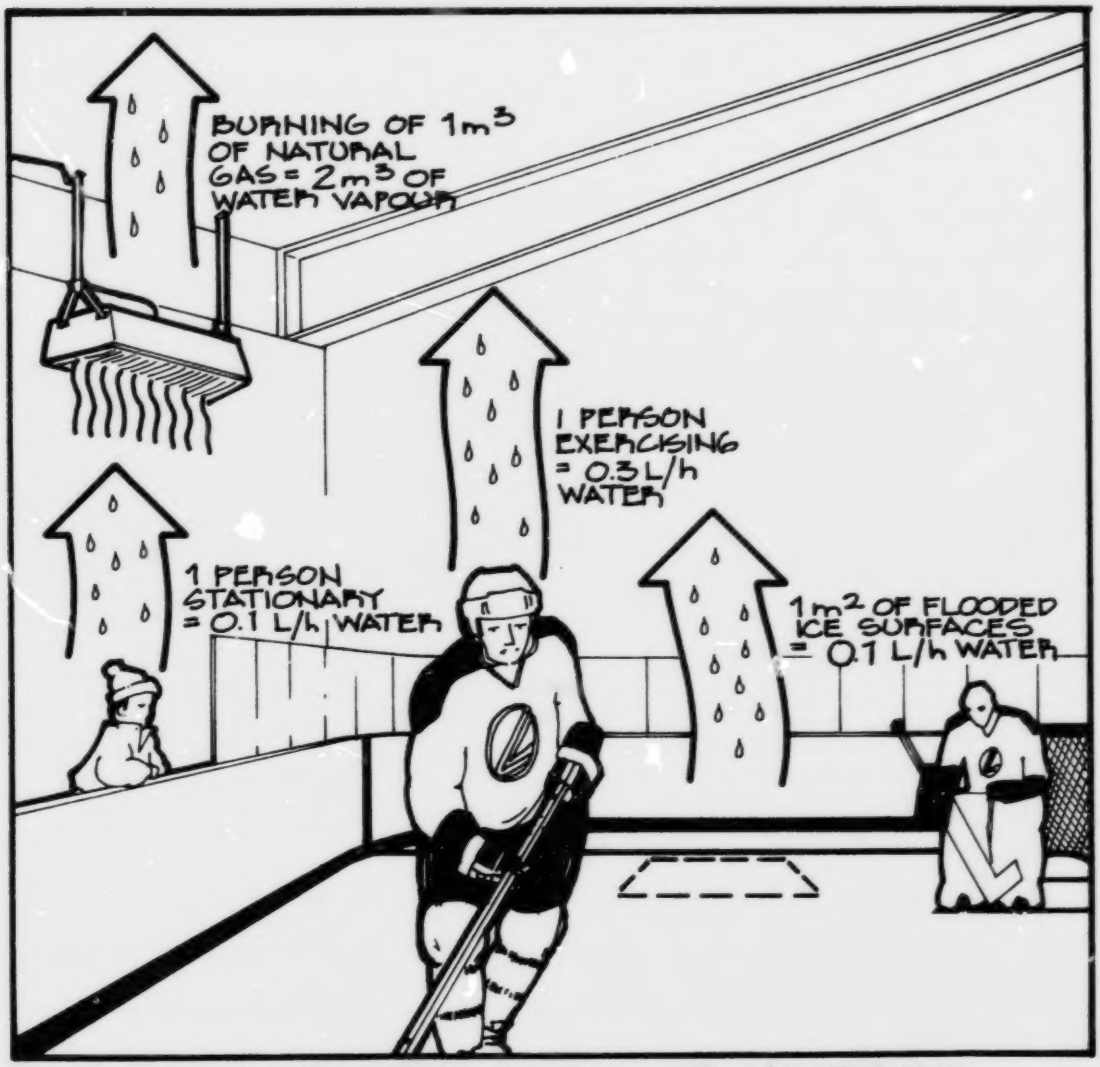
BURNING OF 1m³ OF NATURAL GAS = 2m³ OF WATER VAPOUR
1 PERSON EXERCISING = 0.3 L/h WATER
1 PERSON STATIONARY = 0.1 L/h WATER
1m² OF FLOODED ICE SURFACES = 0.1 L/h WATER

FIGURE 4. EVAPORATION OF MOISTURE

absence of insulation or because of holes in the liner, it reaches the cold underside face of the roof itself.

The water condensed on the elements of roof structure causes them to rust or rot depending on the material used for construction. The excess water then drips onto the ice surface. Sandblasting and repainting the rusted steel construction or replacing the rotted wood members are very time consuming, costly, and, in most cases, require closing the arena to regular operation (resulting in the loss of revenue). If the repairs are not done in time, the damage could lead to structural collapse of the building.

Repair costs of structure damaged in this manner can be quite high. Operation costs increase because more maintenance is needed for the ice damaged by dripping water. This is the problem described as Problem 2. If condensation happens on the underside of the roof and the dripping is allowed to accumulate in the fibrous insulation, Problem 3 and Problem 4 can develop. The insulation blanket not only sags due to increased weight of waterlogged insulation (which probably will open more seams in the liner or burst it), but the thermal resistance of the insulation will also be gradually decreased until it has no practical insulating value at all. In extreme cases of water condensation at the underside of the roof, and low outside temperatures, the ice can form in the insulation cavity with results described in Problem 4.

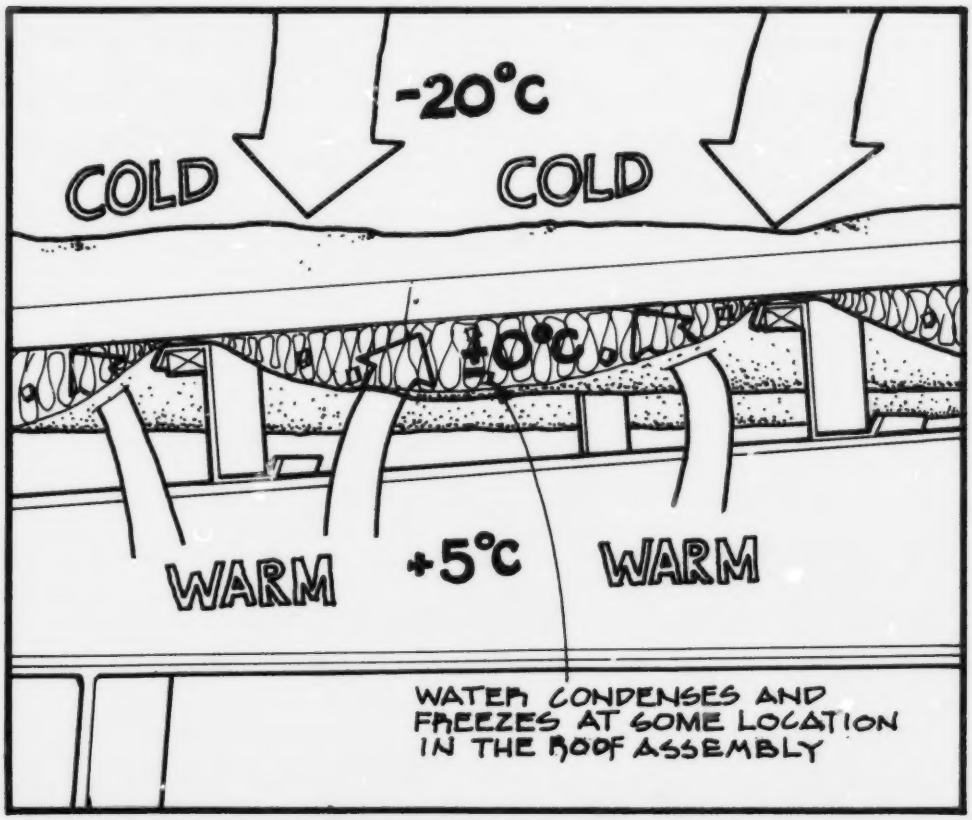

FIGURE 5. DEW-POINT TEMPERATURE

Recommendations

The roof insulation, as described, would not provide an indoor ice arena with satisfactory thermal protection. The steel structure manufacturers are now suggesting various combinations of new, insulated roofs or add-on insulation to existing structures (see Figure 3). In all variations of this type, the insulation blanket is removed from the humid environment of the arena space and the existing metal roof sheet can be converted into the air/vapour barrier.

In new construction, this could be taken care of by proper gaskets between individual metal members and by proper sealing of all fasteners and cut-outs in the roof plane possibly required by mechanical or electrical trades. For an "add-on" roofing system, the interior insulation blanket must be removed. All joints of the exterior existing roof could be made air/vapour tight, for instance, by mopping a glass fibre reinforced asphalt coating on the exterior face of the roof. Then, using spacers, a new roof, consisting of an appropriate thickness of insulation for the given location, and a new steel roof should be installed.

By extending the new top roof sheet beyond the old roof edge, the problematic unsuitable detailing of the roof edge (Problem 1) could be solved at the time of installation of the new roof as well. Increased insulation and the removal of the insulation blanket from the interior of the building could solve problems of condensation forming on the underside of the roof. No ice could

form to become trapped (Problem 3,4) or damage the vinyl liner (Problem 6). The new roof would probably result in a lower energy bill (Problem 8) and a shorter ice preparation period, by decreasing the radiation effect of the roof (Problem 9). Condensate, forming on the underside of the roof, could be eliminated or at least grossly reduced by keeping the roofing metal sheet warmer, thus not allowing the dew point temperature of the humid air to be reached on this critical surface.

An alternative solution to the roof insulation problems could be an application of "in place" foamed polyurethane insulation over the existing metal roof and topped with elastomeric coating for increased waterproofing and ultra-violet ray protection. This application will probably require some new flashing around the edges of the roof. But again, in this application, the insulation is removed from the interior of the building. The effects of thermal expansion and contraction of the metal structure are decreased, which means it is much easier to make the building airtight. The condensation on the underside of the roof will again be eliminated or at least grossly reduced.

Both of these new applications of insulation added to the exterior of the existing roof have an important advantage - no interruption of the normal operation of the arena.

c) Problem 5 - Metal and Concrete Block Wall Structure

The causes of exterior metal walls sweating are similar to those described in the previous chapter. The warm, humid air, coming in contact with the cool surface of the wall, produces condensation when it reaches its dew point temperature at the metal surface. The condensate then drips onto the lower concrete block part of the wall. The capillary action spreads this water into the pores of the concrete blocks. The water then migrates to the surface of the block wall, where it leaches out the mineral salts contained in the concrete and connecting mortar. The visible results are the white spots on the exterior face of the building known as "efflorescence". When this cycle is repeated over the years, crystals of ice and salts formed in the pores of the surface layer of the concrete grow bigger and bigger and finally will result in spalling of the blocks' surface.

Similar action in the wall cavity takes effect during the weeks at the beginning and the end of the arena's operating season. The outside temperatures are higher than the temperature required for the proper operation of the arena. Sweating on the interior face of the metal wall (Problem 5) will probably not occur at this time. It will take place on the cavity face of the interior metal liner, where the warm outside air infiltrating the cavity by numerous joints of the metal wall, will come into contact with the cold metal sheet. Thus, additional water is added into the wall system. Moisture which dropped down on the concrete block is then

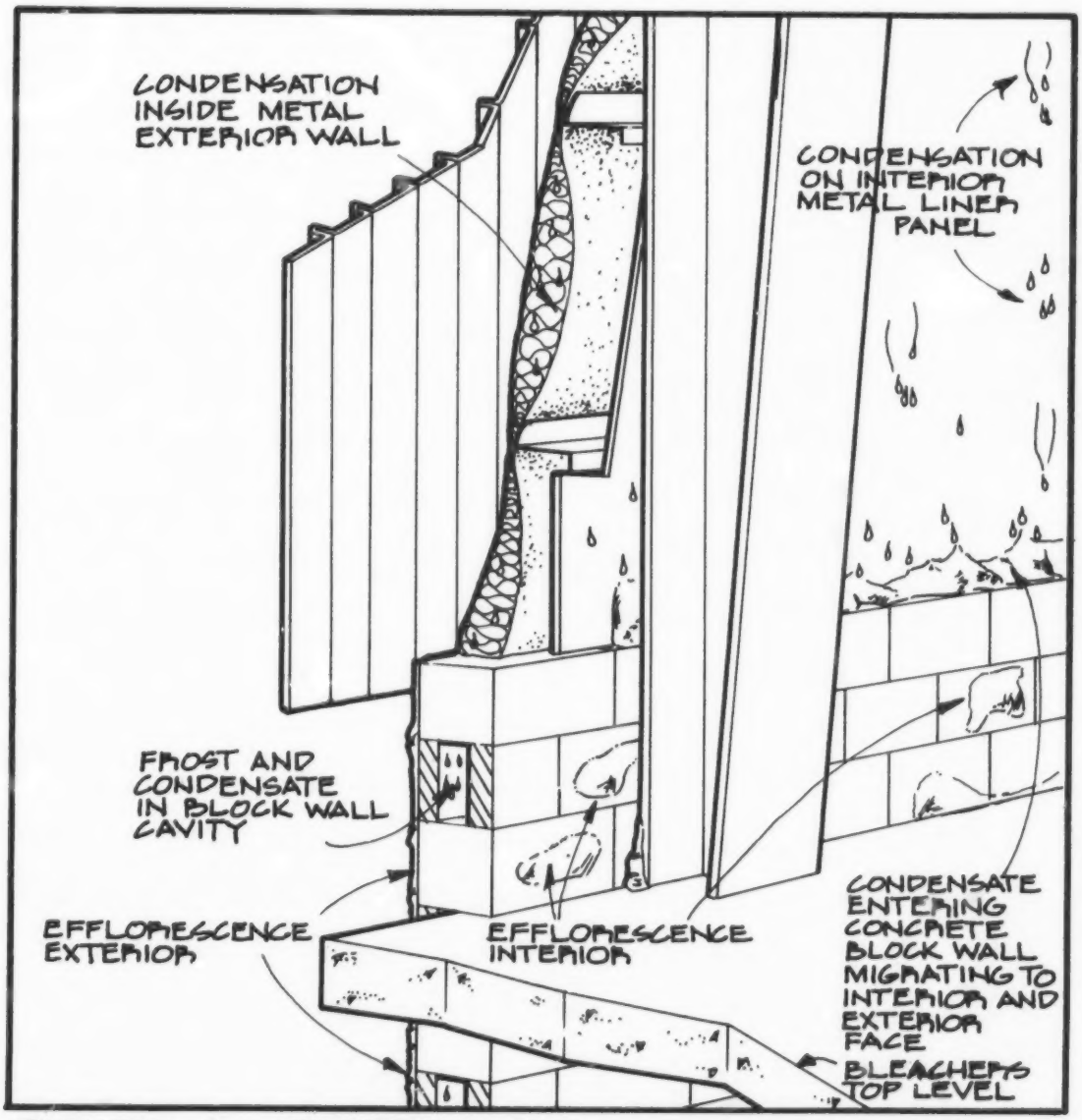
CONDENSATION INSIDE METAL EXTERIOR WALL
CONDENSATION ON INTERIOR METAL LINER PANEL
FROST AND CONDENSATE IN BLOCK WALL CAVITY
EFFLORESCENCE EXTERIOR
EFFLORESCENCE INTERIOR
CONDENSATE ENTERING CONCRETE BLOCK WALL MIGRATING TO INTERIOR AND EXTERIOR FACE
BLEACHERS TOP LEVEL

FIGURE 6. CONDENSATION PROBLEMS AT EXTERIOR METAL WALL AND METAL/CONCRETE BLOCK WALL JUNCTION

driven towards the inner face of the concrete block wall and the efflorescence takes effect there (see Figure 6).

Further condensation can and will occur inside the uninsulated wall block's cavities. Warm air penetrates the cavity by pores in the concrete or cracks in joints, where it then comes into contact with the cold cavity face of the block. The condensation, capillary action and efflorescence cycles begin. The results are usually most pronounced at the bottom of the wall or where a floor slab at top of the seating area penetrates the wall. The reason for this occurrence is that the concrete foundation or slab interrupts the free flow of water on the face of the cavity and the water, by gravity action, finds its way to the outside. Again, depending on the time of year, the moisture migrates to the outside or inside face of the wall, contributing to the wetting of the wall and eventual efflorescence and spalling of the block wall surface.

Recommendations

The sweating of the metal walls and efflorescence on block walls (Problem 5), although having a common cause, must be dealt with separately. The metal part of the wall will need, in the majority of cases, increased insulation to bring the temperature of the inner face above the dew point. This could be achieved by removal of the inner metal liner (at the same time repairs of the liner or replacement of seriously damaged sheets can be conducted). The cavity should be filled with insulation and the proper air

barrier must be installed before the liner panel is reinstalled. It must be emphasized, that to achieve air tightness in this manner is complicated and not always dependable (see below). The metal part of the wall should have an appropriate flashing at its bottom to drain any water penetrated into the wall system to the outside (see Figure 7).

The concrete block part of the wall needs to be insulated as well. This could be achieved in a relatively simple way. The decision must come on the basis of the local conditions. Is it possible to add insulation on the outside of the building? Is there space to add another 100-150 mm of construction all around the perimeter of the building? What would it do to the appearance of the building? Is strapping the exterior face of the block wall and applying the mineral fibre or rigid foam insulation the answer? Proper detailing of connecting the new structure to the old is, of course, essential. The benefit of adding insulation to the outside face will be twofold. Firstly, to install the insulation, the arena will not have to close and interrupt operation. Secondly, if the insulation is added to the outside of both parts of the wall (metal and concrete block), a superior airtightness of the building can be achieved, with all its desirable effects (see Figures 7 and 8).

If this is not possible, insulation must be applied on the interior face of the wall. It must be properly protected against moisture penetration and mechanical damage. At the present time, there are on the market, proprietory insulation systems using rigid

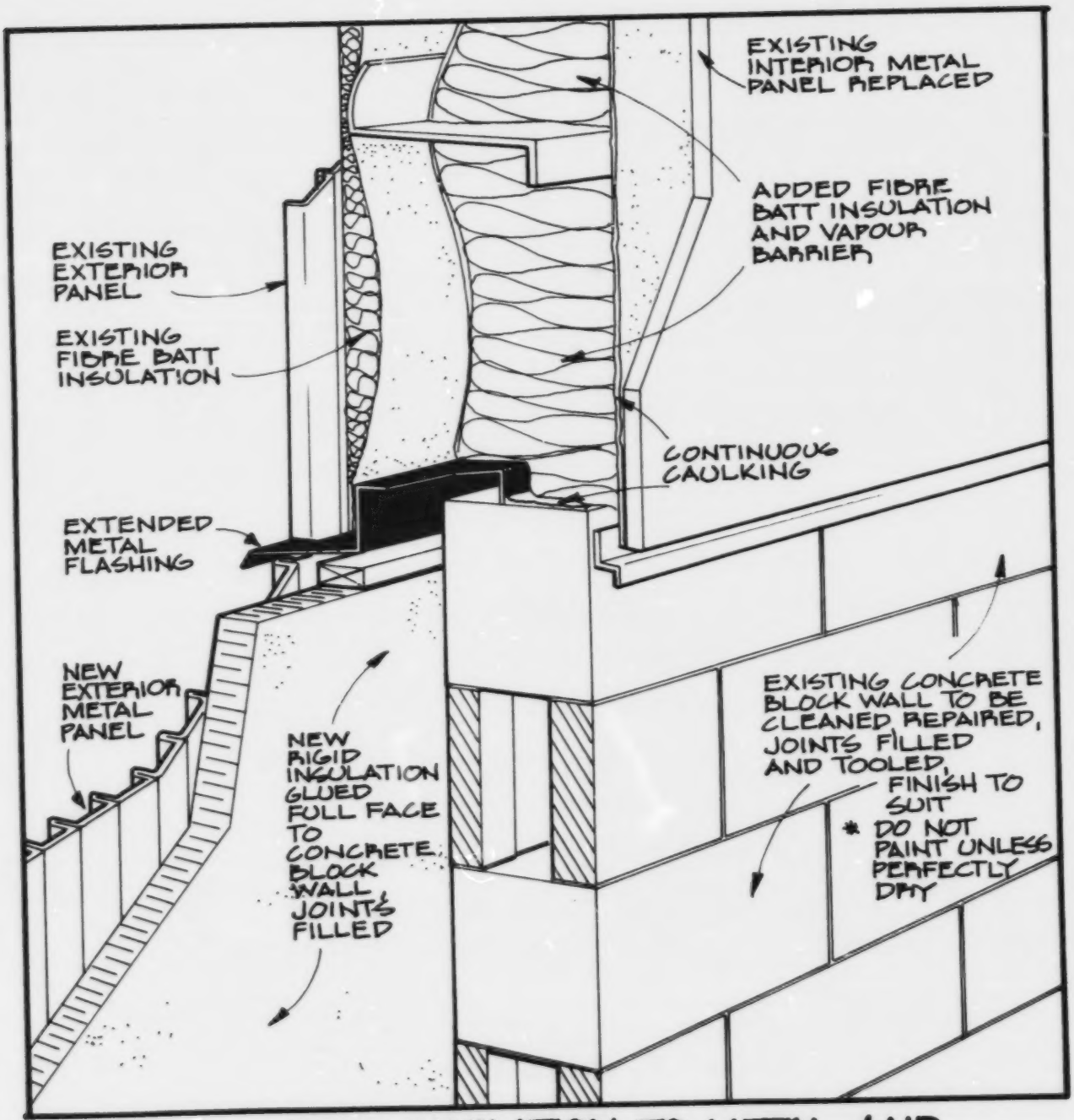
EXISTING INTERIOR METAL PANEL REPLACED
ADDED FIBRE BATT INSULATION AND VAPOUR BARRIER
EXISTING EXTERIOR PANEL
EXISTING FIBRE BATT INSULATION
CONTINUOUS CAULKING
EXTENDED METAL FLASHING
NEW EXTERIOR METAL PANEL
NEW RIGID INSULATION GLUED FULL FACE TO CONCRETE BLOCK WALL JOINTS FILLED
EXISTING CONCRETE BLOCK WALL TO BE CLEANED REPAIRED, JOINTS FILLED AND TOOLED, FINISH TO SUIT
* DO NOT PAINT UNLESS PERFECTLY DRY

FIGURE 7. ADDED INSULATION TO METAL AND CONCRETE BLOCK WALL-EXTERIOR

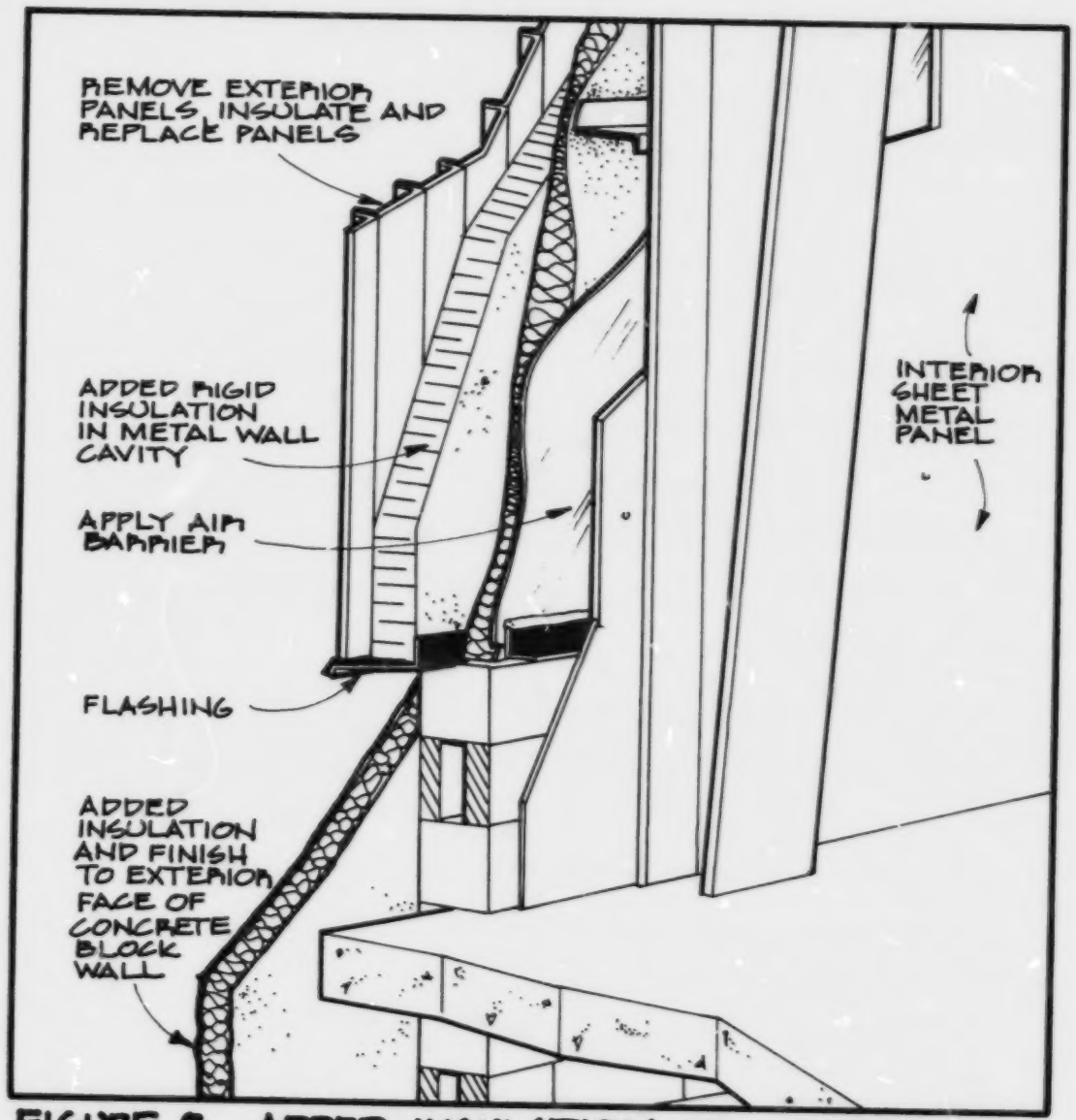
REMOVE EXTERIOR PANELS, INSULATE AND REPLACE PANELS
ADDED RIGID INSULATION IN METAL WALL CAVITY
APPLY AIR BARRIER
FLASHING
ADDED INSULATION AND FINISH TO EXTERIOR FACE OF CONCRETE BLOCK WALL
INTERIOR SHEET METAL PANEL

FIGURE 8. ADDED INSULATION TO - EXTERIOR FACE OF BUILDING

foam insulation with attached hard covering sheets and factory applied finishes (stucco etc.). Application of this kind of insulation is simple and can be done by the arena maintenance staff. It should be stressed, that prior to such an application, the arena owner will require certification from the manufacturer or applicator regarding suitability of the systems for indoor application, fire rating, etc. (see Figure 9).

d) Problem 6 - The Insulation Liner

The insulation vinyl liner can be damaged by improper installation, weight of collected condensate, as discussed above, or by physical action inherent to the activities in the arena (a puck shot). Any of these causes jeopardize the proper function of the liner as an air and/or vapour barrier. Any discontinuity of the air barrier only contributes to the problems discussed earlier.

Damage to the exterior and interior wall metal liner, in most cases, causes only aesthetic problems. Dents, caused by vandals or such accidents as the wall being hit by a hockey puck or moving some heavy objects, usually do not destroy the structural integrity of the wall. Only if the damage is severe, is it justifiable to replace the whole sheet.

Recommendations

If the thermal insulation wrapped in an insulation vinyl liner is to remain exposed to the interior of the building, the liner

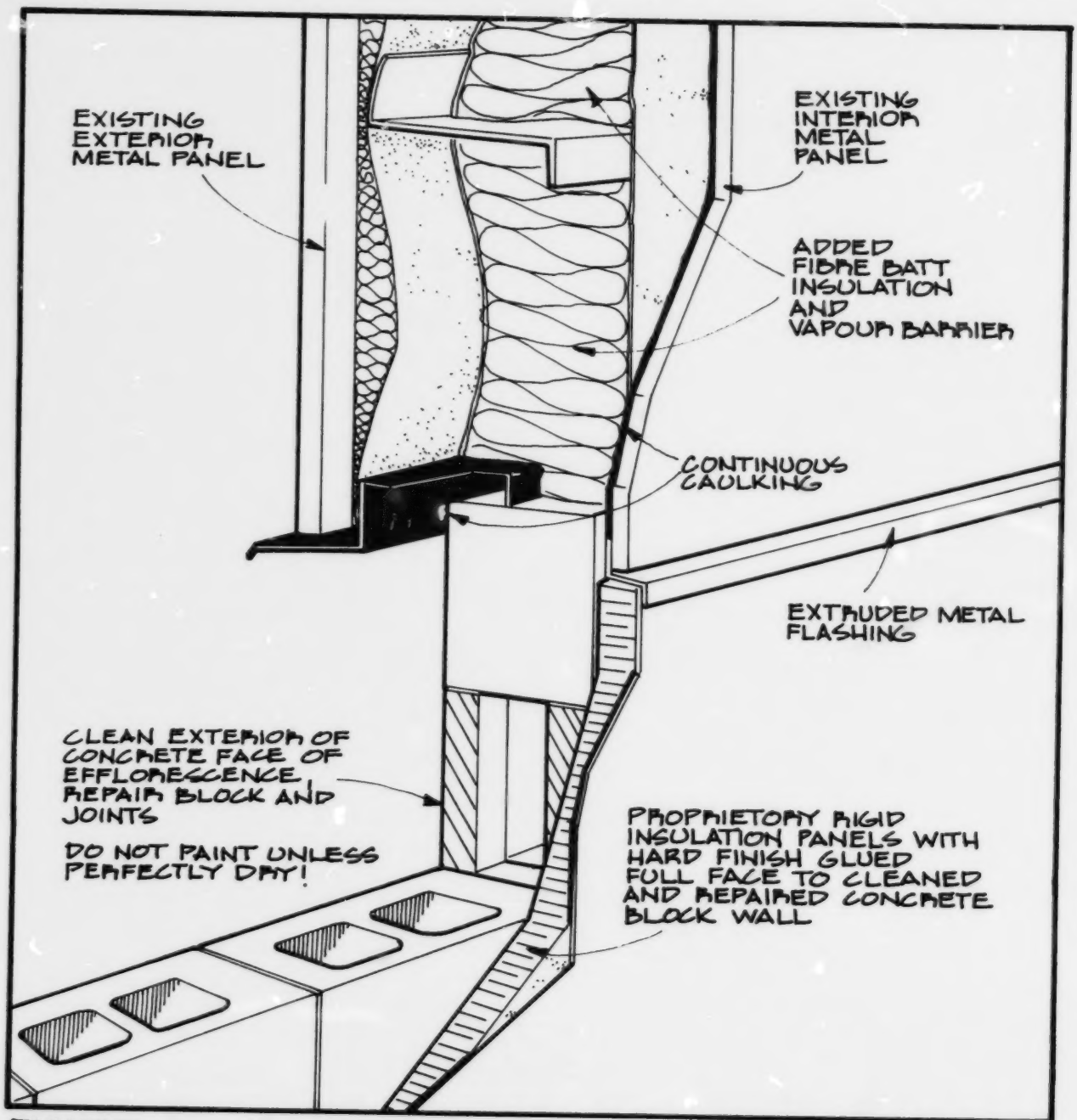
EXISTING EXTERIOR METAL PANEL
EXISTING INTERIOR METAL PANEL
ADDED FIBRE BATT INSULATION AND VAPOUR BARRIER
CONTINUOUS CAULKING
EXTRUDED METAL FLASHING
CLEAN EXTERIOR OF CONCRETE FACE OF EFFLORESCENCE, REPAIR BLOCK AND JOINTS
DO NOT PAINT UNLESS PERFECTLY DRY!
PROPRIETORY RIGID INSULATION PANELS WITH HARD FINISH GLUED FULL FACE TO CLEANED AND REPAIRED CONCRETE BLOCK WALL

FIGURE 9. ADDED INSULATION TO METAL AND CONCRETE BLOCK WALL - INTERIOR

must be frequently checked for damage. Any holes or open seams must be immediately taped or otherwise repaired. To protect the liner against puck damage, wire mesh netting strung below the liner is recommended.

Where exterior metal cladding extends close to the ground and if the parking lot is located immediately adjacent to the building, then position parking curbs are recommended.

If there is an overhead door in the building used to provide access for vehicles, position a rigid post outside each corner of the door opening. These posts will prevent a vehicle from accidentally backing into the corner of the door opening and damaging the building.

e) Problem 7 - Rusting of Metal Building Elements

The corrosion of the metal building elements is, structurally, the most serious effect of the moist humid air on the building. The rusty building is not only unsightly; but, if the corrosion remains unchecked, it could also lead, in time, to serious structural damage and eventually result in building collapse. Structural members (columns, beams, roof trusses, etc.) must be inspected annually for signs of corrosion, any rust must be removed and effected areas coated with a rust inhibitive paint suitable for application to structural steel and to the existing paint.

The Canadian Sheet Steel Building Institute describes the metal components and the effect of humidity on the arena building in this way:

Sheet steel cladding, and occasionally secondary structural members, are supplied with a zinc coating over the steel sheet. This zinc coating is called galvanizing and provides a corrosion protection for the steel. In the presence of an electrolyte (impure water), the zinc coating will sacrifice itself to the steel and corrode first before the steel.

There is another metallic coating system, used in place of galvanizing, which has an aluminium-zinc alloy coating instead of zinc alone. This type of coating provides the same sacrificial protection as the galvanizing.

As well as the metallic coating, steel components are usually supplied with some type of paint coating. The structural steel members which are generally not furnished with a metallic coating are supplied with a rust inhibitive primer. Sheet steel cladding is usually supplied with a factory applied paint system over the metallic coating. Such paint systems can provide significant additional corrosion protection to the steel.

As a general rule, the thicker the steel member, the less effect surface rust will have on its structural performance. The main structural members of a building can be scraped and repainted when the amount of rust warrants. These structural members should be thoroughly inspected, in all accessible locations, on a regular

basis, to assure that severe rusting is not occurring in some obscure location.

The rusting of secondary structural members and sheet steel cladding should be corrected without delay before the relatively thin structural steel member is affected. In general, galvanized structural members and cladding will provide years of service without showing any signs of rust, as long as moisture is not allowed to remain on the galvanized surface for long periods. If water is allowed to accumulate, the zinc coating, and then the steel, will corrode at an accelerated rate.

Recommendations (provided by Canadian Sheet Steel Building Institute)

An occasional thorough cleaning of pre-finished material can extend the service life and help to maintain the appearance of the finish. Simply washing with plain water using hoses or pressure sprays is often sufficient. Waxing is an additional method of prolonging the service life of pre-finished material.

In areas where heavy dirt deposits dull the surface, a solution of water and detergent may be used: 100 ml (1/3 cup) of a typical laundry power detergent per 4 litres (1 gallon) of water. A soft bristle brush should be used for scrubbing followed by a clear water rinse.

Mildew may occur in areas subject to high humidity. To remove mildew along with the dirt, the following is suggested:

100 ml (1/3 cup) laundry detergent

200 ml (2/3 cup) trisodium phosphate (TSP)

1 litre (1 quart) 5% sodium hypochlorite solution (laundry bleach)

3 litres (3 quarts) water

Use in a well ventilated area. A clear water rinse should follow.

Solvent and abrasive cleaners should be avoided. Caulking compounds, oils, grease, tars, wax and similar substances can be removed with mineral spirits applied only to the areas that are affected. Detergent cleaning and a thorough rinsing should following the use of solvent.

Painting can also be an effective solution to corrosion problems. There are a number of different applications for paint systems in an arena. There is the painting of the structural members, painting the sheet steel cladding (both inside and outside) and painting of the other fixtures inside the building (e.g. seats, floors, partitions).

Selecting a paint to use on the building fixtures will depend upon the application, but usually a brand name household or commercial paint would be adequate. This paint is intended

basically for appearance and not for providing corrosion protection.

The main structural members, as well as the secondary structural members, need to be coated with a rust inhibitive paint of some kind unless they are protected with a metallic coating (such as zinc) or a special protective coating. Any painting schedule should try to inspect and touch-up all of the steel members, not just those places that are easily accessible.

The painting of sheet steel cladding can, in some cases, pose a particular problem. Basically there are two painting requirements that arise: (1) the cladding was supplied prepainted, and after a number of years in service, the paint requires a touch-up in places or a complete repainting; or (2) the sheet steel cladding was supplied unpainted with the intention of painting after installation.

When repainting over existing prepainted cladding, a number of factors should be considered in order to achieve the best results.

(1) It is important to select a primer that is compatible with the existing paint system. Most often in eastern Canada, sheet steel cladding for recreational buildings is supplied with a modified silicone polyester paint system. A paint manufacturer should be consulted for advice regarding selection of the proper paint system for repainting.

(2) Before painting, the surface must be cleaned of all dirt, rust or other substances.

(3) The paint should be applied in strict accordance with the directions of the paint supplier.

(4) When choosing a colour, consider that a lighter colour will last longer on roofs since the lighter colour will better resist the harmful effects of the sun. Aesthetic considerations, however, often dictate that dark colours be used on roofs. In doing so, the owner must accept that the roof will likely fade faster and need to be repainted more frequently than if a light colour is used.

(5) When only a touch-up is required, keep the touch-up to a minimum since this paint will not last as long as the original paint system. A small artist's brush or air brush should be used to apply the paint to a small surface.

Field painting of galvanized sheet steel after installation can create problems in many buildings. Unpainted galvanized sheet steel supplied by Canadian steel mills is typically coated with a chemical passivation treatment intended to control what is called wet storage stain (also known as "white rust"). White rust can occur where the galvanized material is subject to certain temperature and humidity, commonly occurring when the formed panels are stacked at the construction site waiting to be erected. White rust is, essentially, corrosion products of the zinc coating and will eventually lead to the

rusting of the steel if it is allowed to continue. To control this problem, the passivation treatment is regularly applied to the unpainted sheet steel. The passivation, however, has a limited effectiveness; therefore, the outdoor storage of sheet steel products onsite, awaiting erection, should be as brief as possible.

If a sheet steel product is to be field painted after erection, it is necessary to specify that the galvanized material be supplied unpassivated. The manufacturer will then order this material from the steel mill and fabricate the product. Galvanized material supplied this way can then be painted using an appropriate paint system and application procedure. Galvanized sheet steel that has been supplied without specifying that it be unpassivated cannot reliably be painted. With a few exceptions, paint will not adhere to passivated sheet steel and often flakes off after a short time, especially in a humid environment. There are specialized paint systems available that can be used, but the proper application of these paints is important and there is likely to be an additional cost. Any owner who is thinking of field painting galvanized sheet steel products should be careful in selecting the proper paint system and application methods.

f) Problem 8 & 9 - Energy Considerations

It is generally accepted that in Canada, the cost of heating the building can be the most significant portion of the operating budget. Indoor ice arenas could be considered an exception to the rule. The ice making, lighting, ventilation and dehumidification costs are certainly higher than the cost of heating the spectator areas (if we only consider the arena, and the necessary heating of other spaces associated with the arena proper are disregarded).

Insufficient insulation of the walls and roof plus high air leakage, common to this type of metal structure, creates high energy demand for ice preparation. Heat flow into the ice sheet comes, surprisingly, only 1-6% by conduction (heat flow from the concrete slab around the rink), 30-70% by convection (heat carried to the ice by air movement) and 30-70% by radiation from interior surfaces of roof and walls.

Conduction is insignificant, convection can be controlled by dehumidification and shielding the ice from air currents. Radiation is a more serious factor than previously realized. The temperature differential between the 40°C at the underside of uninsulated roof in summer and -4°C of the ice causes a high emission of radiation from roof to ice, increasing energy demands on ice preparation and maintenance. Lighting energy costs, which used to be negligible when the electricity was inexpensive and the operating season short, can rise to form a substantial part of the operating budget.

Recommendations

Efficient dehumidification equipment and proper maintenance and operation is essential for an arena. It is very difficult to recommend the capacity of the dehumidification unit/s because it depends on the volume of air with which the machinery will have to deal (i.e. the size of the building and operating conditions). Therefore, the design of the dehumidification plant cannot be generalized and has to be prepared by a responsible consulting engineer for a specific case.

A dehumidification plant for an arena of the following dimensions: 35 m x 75 m x 8m, according to available estimates costs approximately $36000 (1986, two dehumidifiers). The energy saving payback period is estimated at five to six years of operation.

It is important to know, that an air conditioning system, instead of dehumidifiers, would be inappropriate in an ice arena. The presence of 1500 m^2 (or more) of ice in the rink keeps the space cool even in the warmest weather. Therefore, the air conditioning system will never "come on" because the arena space is cooler than the possible thermostat setting of an air conditioning system.

Substantial savings on operation costs can be achieved by an installation of a low emmissivity suspended ceiling. This ceiling, consisting of aluminum foil on fiber glass backing, is suspended from existing structure on stainless cables (see Figure 10).

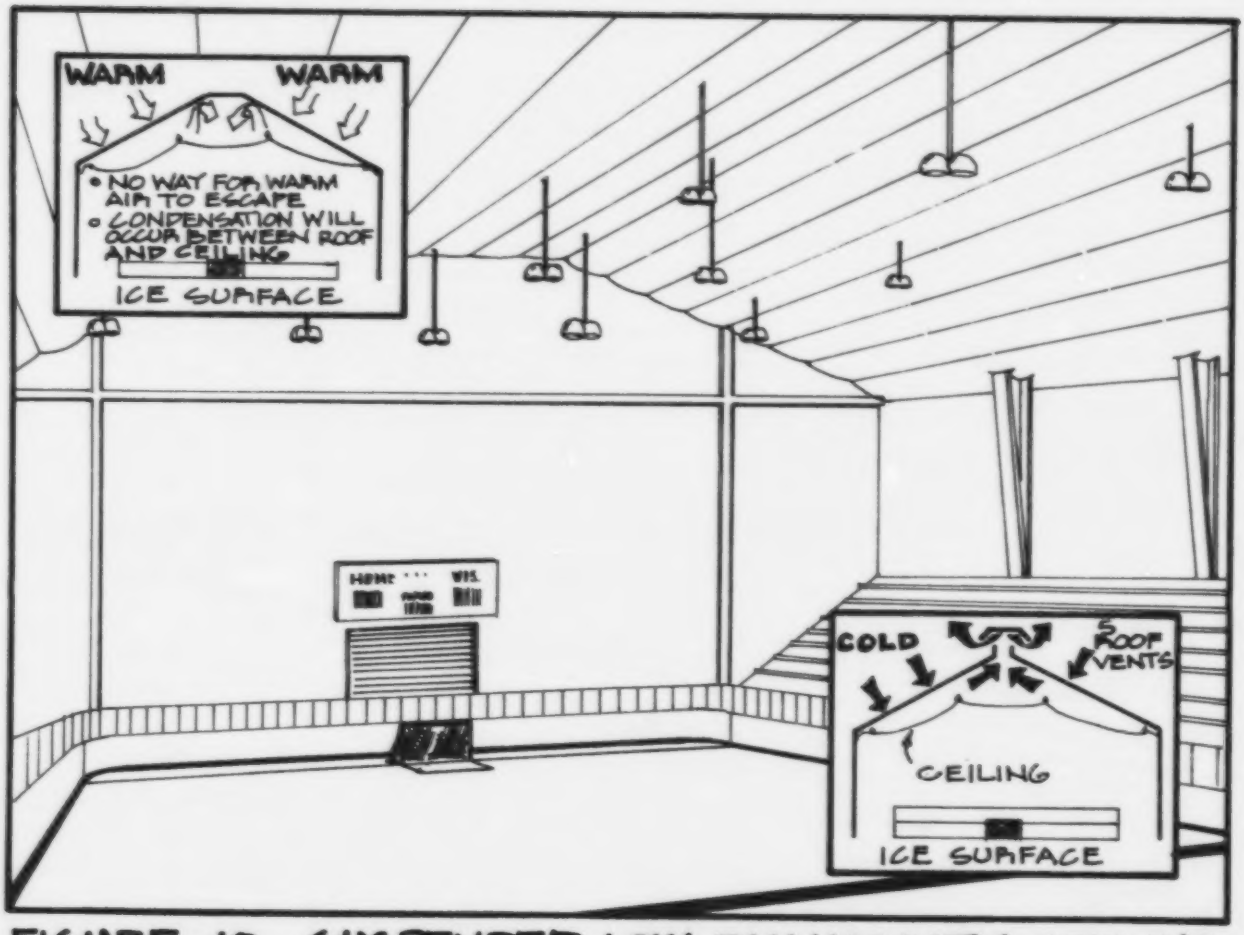

FIGURE 10. SUSPENDED LOW EMMISSIVITY CEILING

Emmissivity is a factor which indicates the ability of an object to radiate heat. The higher the emmissivity, from 0 to 1, the better is the radiating ability of the object. The emmissivity of metal, even painted white, is 0.8 but of highly polished aluminum foil it is only 0.05. Even though the aluminum surface will dull with time and its emmissivity will become 0.2, this suspended ceiling effectively breaks the flow of radiated heat from the roof towards the ice sheet. Consequently, it reduces the load on the refrigerating plant and thus energy savings will be achieved.

Additional savings occur in the lowering of lighting energy demand. The aluminum foil acts as a reflector of light. Because the ceiling traps heat radiated into it from the underside of the roof and does not transfer it further, it remains relatively warm. Humid air rising from the ice does not, therefore, come into contact with a cold surface. The danger, of course, exists that the air by-passing the loosely suspended ceiling will reach the cold underside of the roof. The space between the suspended low emmissivity ceiling and the underside of the roof must be ventilated by using exhaust ventilators. Better still, the additional insulation and low emmissivity ceiling should be installed at the same time.

Available reports confirm that installation of a low emmissivity ceiling pays for itself in approximately two years. Direct energy savings are achieved in approximately 50% lighting demand reduction for most of the operation period (at the time of public skating, practices, figure skating). Energy savings in ice preparation are achieved by lowering demand on cooling the brine returned to the plant after circulation in the cooling pipe system. As reported, before installation of the ceiling, the temperature difference in "brine-in" and "brine-out" was 2.5-3.5°C; after installation the temperature difference dropped to 0.6-1.5°C.

CONCLUSION

High humidity is a problem facing managers of indoor ice arenas. It is not a problem that can be ignored. Clearly, steps must be taken to deal with, not only the symptoms, but also the actual source of the problems.

We hope this paper assisted in identifying a number of causes and possible solutions to common problems that occur in arenas due to high humidity levels. Properly planned maintenance programs and early attention to problems will reduce longterm operational costs and help you in extending the life of your arena.